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ECOLOGICAL RESTORATION IN CALIFORNIA: CHALLENGES AND PROSPECTS

MICHAEL C. VASEY[1,2] AND KAREN D. HOLL[1]
[1]Department of Environmental Studies, University of California, Santa Cruz, 1156 High St., Santa Cruz, CA 95064
[2]Department of Biology, San Francisco State University, 1600 Holloway Ave., San Francisco, CA 94132
mvasey@sfsu.edu

ABSTRACT

Given the rich biological diversity in California and dramatic loss and modification of its habitats, populations, species, and ecosystems, a concerted effort has emerged to restore large areas of the state's public and private lands. Under these circumstances, ecological restoration represents an important element in the strategy to conserve numerous at-risk species and maintain vital ecosystem services. After reviewing the various motivations for ecological restoration, we identify some of the key challenges, both practical and theoretical, that are likely to affect the success of restoration efforts. We describe a shift in defining restoration success from a focus on recreating historic "pristine" ecosystems to viewing restoration in a dynamic landscape context in which realistic novel ecosystems are accommodated. These accommodations are necessitated by a broad array of challenges that include several global change factors. Finally, we argue that prospects for successful ecological restoration will be enhanced by emphasizing landscape-scale resilience and incorporating restoration into a regionally-coordinated, active adaptive management program.

Key Words: adaptive management, California, ecological restoration, global change, novel ecosystems, resilience.

California is renowned for its extraordinary levels of biological diversity. The California Floristic Province has been recognized as one of 25 global biodiversity hot spots (Meyers et al. 2000; Konstant et al. 2005) with an estimated overall endemism of vertebrates and insects and other invertebrates exceeding 50% and of vascular plants approximating 35% (Schoenherr 1992). This degree of endemism is remarkable for a large continental region located in the temperate zone.

Numerous reasons have been advanced to explain this diversity (e.g., Stebbins and Major 1965; Stebbins 1978; Raven and Axelrod 1978, Davis et al. 1997). These fall into a combination of three premises: (1) California has served as a refuge for a flora and fauna that was once much more widespread over western North America during the Middle-Tertiary but that became progressively restricted in range due to cooling and drying of the interior; (2) California served as a cauldron of evolution during the Pleistocene, especially among annual plants and insects, as numerous glacial and inter-glacial cycles provoked frequent migratory shuffling of species assemblages while the advent of an extreme Mediterranean climate drove adaptation to a higher frequency and intensity fire regime; and (3) California presents a remarkably heterogeneous combination of geology, soils, hydrology, climate, and topography comprising a fine-grained substrate on which various species assemblages have been able to differentiate. The net result of this diversification is an estimated 300 natural communities, 178 habitat types (Schoenherr 1992), 10 floristic provinces, and 24 floristic sub-provinces (Hickman 1993). A key point is that change, and particularly the recent climatic changes during the Pleistocene, have been an important driver in California's biotic diversification. Change is not inherently bad, but it clearly can have important ecological and evolutionary manifestations.

Hoekstra et al. (2005) list most of the California ecoregion as critically endangered based on the extremely high habitat conversion rate relative to area protected. Noss (1994) and Noss and Peters (1995) note a range of highly threatened California ecosystems, including coastal strand and dune, southern California coastal sage scrub, large rivers, riparian forest and wetlands, native grasslands, old growth ponderosa pine forests, cave and karst systems, and ancient Pacific Northwest forests. Less than 10% of the original extent of vernal pool habitat (Zedler 2003) and about 10% of tidal wetlands (Zedler 1996) remain. More than 99% of grasslands in California are now dominated by non-native species (Davis et al. 1997). This habitat loss and transformation has led to extensive fragmentation and isolation. Non-native invasive species and various kinds of pollution add additional stresses to these habitat remnants. This combination of conditions may lead to an "extinction vortex" (Gilpin and Soulé 1986) that, absent intervention, can progress down an irreversible path toward species extinction.

Super-imposed upon the California landscape is the influence of human populations. Beginning with the first establishment of human settlements between 12,000 and 15,000 yr ago, humans have significantly influenced the distribution and composition of communities. For example, Anderson (2007) reviewed the use of fire by Native Californians to improve hunting, provide defensible areas surrounding villages, and enhance germination of desirable species, among other reasons. Today, human populations have an even greater impact on species composition and biodiversity, as there are now approximately 36 million people in California and a growth rate of 13.6% per decade (U.S. Census Bureau 2006). Understandably, future population growth has provoked alarm at prospects for the future of biodiversity in California (e.g., Jensen et al. 1993). In particular, even at the level of popular conservation advocacy (Brower and Chapple 1995), recognition has emerged that preservation of California's remnant wild ecosystems is not enough; rather, it is considered imperative that we begin the process of restoring and reconnecting threatened habitats if we are to prevent the current and growing extinction crisis (Wilson 2002).

In this review, we explore the relationship between ecological restoration and biodiversity conservation in the future. To set the stage for this analysis, we evaluate the range of motivations and endpoints for restoration in California and elsewhere. We then illustrate a number of challenges confronting restoration efforts, focusing on issues of landscape context and global change. Finally, we review contemporary literature in restoration ecology that poses some alternative prospects for how to best adjust conservation strategies to mesh with these overarching realities. While the application of these approaches is critical to conserving biodiversity in California, they are equally compelling in a wide array of venues experiencing similar conservation challenges.

Motivations and Endpoints for Restoration

Restoration of damaged ecosystems in California and worldwide is motivated by myriad reasons (Ehrenfeld 2000; Clewell and Aronson 2006) and is undertaken by a wide array of actors, ranging from volunteer community groups focusing on small (sometimes less than one hectare) sites to large multi-public agency consortiums engaged in projects involving thousands of hectares (e.g., the South Bay Salt Pond Restoration Project along the shores of the San Francisco Bay). Often restoration is initiated to achieve specific conservation goals, such as preventing the extinction of endangered species and the habitats on which they rely (Ehrenfeld 2000). For example, restoration of dune habitat in Lobos Valley on the Presidio of San Francisco was motivated in large measure by the desire to recover a federally listed endemic annual plant species, the San Francisco Lessingia (*Lessingia germanorum*). This effort increased the number of individuals from the low hundreds to approximately one million (Albert 2001), while also restoring an ecological educational resource in the heart of San Francisco (Holloran 1998). Many restoration projects also aim to provide important ecosystem services for humans such as water treatment provided by wetlands or rehabilitation of drastically disturbed ecosystems, such as mines and areas contaminated by chemicals that may negatively affect human health. Federal and state laws (e.g., the Endangered Species Act, Section 404 of the Clean Water Act, Surface Mining and Reclamation Act) recognize these public values and mandate restoration of certain habitats or species. Clewell and Aronson (2006), however, highlight that restoration may be motivated by other reasons, such as attonement for environmental damage, reentry into nature, renewal of the nexus between nature and culture, and spiritual renewal. Indeed, many efforts to remove invasive non-native species in California are not mandated by law and are largely staffed by volunteer labor.

Our goal here is not to provide an exhaustive list of motivations for restoration, but rather to note the diversity of reasons behind restoration that will necessarily lead to differing goals of restoration projects. The increasing recognition of these different goals is reflected in the broadening definition of restoration. Early publications in the field of restoration strove to distinguish between restoration (an effort to restore 'predisturbance' conditions) and efforts that aimed to reclaim or rehabilitate certain, but not all, species and ecosystem functions (Cairns 1983; Bradshaw 1984). In contrast, the recent Society for Ecological (SER) definition of ecological restoration is much more inclusive. Ecological restoration is now defined as "intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" (SER 2004). This newer definition reflects the varied goals of different restoration projects, as well as the recognition that given historical contingencies and the dynamic nature of ecosystems, it is impossible to achieve a highly fixed restoration endpoint. As we argue later, changing global conditions make a broader view of the endpoint of restoration essential.

Trying to restore an exact replica of the full suite of pre-disturbance species is not the sole reason for restoration or, perhaps, the most publicly compelling. Yet, biotic diversity is likely to benefit from ecological restoration no matter what the motive. What is essential is that the goals of each restoration project are clearly stated at the outset, and reflect a certain degree of consensus among parties involved, so that the degree of success of the restoration project can be evaluated (Ehrenfeld 2000; Holl and Cairns 2002).

Challenges for Ecological Restoration in California

Although debates about the motivations and endpoints of restoration are longstanding, increasing recognition of the temporal and spatial scale of human alteration require us to re-evaluate the goals of restoration in California and elsewhere. Here we discuss how the spatial scale that is necessary to restore ecosystem processes in the face of increasing impacts of global change will necessarily change how restoration is implemented and its success evaluated. Despite the diversity of actors and scales of projects, a common thread tying most restoration efforts together is that they are narrowly confined to a given piece of land, waterway, or particular habitat type (e.g., tidal wetlands). Although it is widely recognized that the long-term success of restoration is dependent on the landscape-matrix in which it is embedded, this recognition is rarely put into practice (Holl et al. 2003). Recent studies demonstrating the ecological importance of cross-habitat subsidies (Polis et al. 2004) have served to reinforce the key role adjacent ecosystems can play in the ecological health of target restoration habitats.

Considering restoration in a landscape context becomes particularly critical when viewed through the lens of the serious challenges to ecological restoration now represented by global change. Global change agents that may dramatically affect ecological restoration in the future include: (1) several related phenomena associated with rapid climate change including an increase in temperature, sea level rise, altered precipitation patterns, and increased extreme weather events; (2) the introduction of invasive non-native species, including disease microbes; (3) the atmospheric deposition of pollutants, e.g., nitrogen, and their influence on biogeochemical cycles; and (4) changing socio-economic patterns that affect land use practices (Vitousek 1994; MEA 2005). Many of these are discussed in more detail in other articles in this special issue of *Madroño* that is dedicated to exploring the topic of ecological restoration in a changing world using case studies from California (Suttle and Thompson 2007; Callaway et al. 2007; Purcell et al. 2007; Rein et al. 2007; all in this volume).

Climate Change. Potential developments associated with rapid climate change may represent the most important and least appreciated problem facing restoration practitioners (Harris et al. 2006). There are now clear signals that climate change is affecting a host of biotic relationships (e.g., Parmesan and Yohe 2003; Root et al. 2003; Thomas et al. 2004; Parmesan 2006). With a Mediterranean climate, California is particularly vulnerable to changes in rainfall patterns, snow pack storage, hydrology, temperature, and sea level rise (Callaway et al. 2007). Whereas past efforts to conserve and restore at-risk species have focused on a restricted set of habitats impacted by large human populations (e.g., wetlands and coastal dunes), it is now likely that some of the most at-risk species are those that inhabit a broad array of environments and, absent climate change, would be considered safely protected, such as high Sierran endemics and isolated edaphic endemics with nowhere to migrate if local climate becomes unfavorable. In this dynamic environment, active intervention and strategic ecological restoration and management may be the only possible solution for "life boating" several species through this episode of rapid climate change. It is likely that major investments in current ecological restoration projects will need to be modified to account for problems such as rapid sea level rise and other predictable climate-related phenomena, such as altered rainfall patterns. These rapid climate changes, in other words, assure that historical ecosystems will not serve as a faithful reference template for future restored habitats.

Invasive Species. The challenge of invasive species to ecological restoration is all too well known (D'Antonio and Myerson 2002; D'Antonio and Chambers 2006). It is safe to say that the vast majority of ecological restoration activities in California are beset with a suite of non-native invasive species. In an ideal world, restoration would involve stimulating ecological processes, such as fire, natural succession, and sediment deposition that would lead over time to desired natural communities. When non-native invasive species enter the system and set off in unpredictable trajectories, they act to potentially exclude desirable native species and undermine desired outcomes. Since these non-native species usually come from other Mediterranean regions (Major and Barbour 1988) they are well-suited to California's Mediterranean climate and thrive under current disturbance regimes. Further, non-native invasive diseases, such as *Phytopthera ramorum*, the agent causing Sudden Oak Death, and West Nile virus impact natural populations of common species, such as oaks and corvid birds, creating trophic impacts to various levels of species assemblages. The challenge of invasive species, like climate change, may represent a virtually intractable reality that will simply have to be accepted and integrated into ecological restoration goals and practices (D'Antonio and Meyerson 2002; Keeley 2005). The omnipresence of invasive species may be the most powerful argument of all that there is no turning back to some vision of a "pristine" historic ecosystem in California.

Atmospheric deposition. The challenge of atmospheric nitrogen deposition is an insidious phenomenon that affects several ecosystems in California. For example, in species rich serpentine grasslands located in areas with high volumes of automobile traffic, nitrogen deposition promotes the success of non-native annual grasses that suppress native annual herbs which are utilized by rare butterflies such as the Bay Checkerspot, consequently reducing the population viability of this endangered species (Weiss 1999). In southern California, montane chaparral and yellow pine forests are impacted by the combination of both ozone and nitrogen pollution due to summer smog inversion effects (Fenn et al. 2003). While above-ground biomass increases due to a fertilization effect, below-ground fine root mass and carbohydrate allocation are decreased, resulting in heightened vulnerability of these communities to wild fire. Also, nitrate runoff is increased dramatically, causing eutrophic impacts to aquatic habitats that are influenced by this runoff. These are just a few of the manifestations of a broader problem involving the general disruption of global biogeochemical cycles due to pollution. Similar to climate change, the effects of pollution are large-scale and rapid relative to geological time. However, their presence is not directly appreciated in the typical time scale of ecological restoration planning and implementation. It is likely that disruptions of biogeochemical cycling are another major factor that is shaping ecological restoration activities in ways that are still yet poorly understood but that will increasingly influence restoration trajectories.

Land-use practices. A final element of global change that merits attention is the socio-economic drivers of land use practice (Vitousek 1994; MEA 2005). Land use practice in California is governed by a complex web of national, state, and local policies that attempt to protect the public trust (e.g., conserve natural resources) while contending with a majority of lands that are privately owned (Jantz et al. 2007). As local economies increasingly become part of a globalized market, unexpected changes in global economic conditions (e.g., new markets or lost markets) can have major impacts on local land use patterns (Lambin et al. 2001; Wadley et al. 2006). For example, a relatively sudden surge in the demand for wine can lead to large-scale loss of oak woodland and chaparral habitat on slopes surrounding California's coastal and interior valleys. Declines in prices of beef can cause ranchers to sell their ranches for suburban home development. Development of homes in flood plains in the Sacramento Valley can affect the ability to create setback levees and to restore riparian forests. All of these local and regional economic phenomena are today linked to a global economic engine that is highly dependent upon factors that transcend California's economy.

Importance of Social Context

Although it is clear that restoring ecological processes will require large-scale coordination, a major challenge is how to create institutional mechanisms that will coordinate and support restoration activities at landscape and even regional scales among a diversity of actors over extended periods of time. There are numerous examples of this sort of coordination ranging from Coordinated Resource Management and Planning groups confined to single watersheds to the CALFED Bay-Delta Authority that encompasses the entire drainages of the Sacramento and San Joaquin rivers (approximately 40% of the land area of California). A promising example is the 2003 law (SB 107) creating a California Natural Communities Conservation Program (NCCP). California's NCCP focuses on natural communities in which at-risk species are found, but it also takes a broader landscape and/or regional approach to conservation strategies. For example, a Yolo County Habitat Conservation Plan (HCP/NCCP) currently underway (2006) involves a Joint Powers Agreement between several cities and Yolo County. A recent scientific advisor's report pertaining to this Yolo HCP/NCCP (Spencer et al. 2006) outlines a series of management recommendations that involve restoration practices that are designed to improve habitats for a variety of at-risk and more common species. The virtue to such a plan, when and if adopted, is that local governments can create zoning and other land use regulations that have greater potency in guiding land use decisions and practices than virtually any other public policy mechanisms (Jantz et al. 2007).

Unfortunately, these NCCPs and HCPs generally do not go far enough to engage the broader public, including multiple restoration actors, in strategic conservation and restoration activities. Rather, there is still a perception that these conservation plans have a long way to go to reconcile the inherent conflicts between human land use practices and the preservation of biodiversity (Feldman and Jonas 2000). Also, analyses of the focus on listed species for multispecies conservation planning has come under criticism for its inadequacy (Rubinoff 2000; Rahn et al. 2006). But, the recent passage of a strengthened law and the wave of new NCCP proposals underway may represent important forerunners of the kinds of institutions that ultimately could be applied to this need for landscape and regional coordination.

Such efforts to coordinate actions are necessary not only because of the spatial scale of such projects, but also because a reactive countermovement has emerged that presents a considerable level of social resistance to some ecological restoration activities (Gobster 2000). This social resistance can create major roadblocks to restoration activities that impact both the cost and timeliness of restoration implementation. Social resistance can occur both in an urban context, as with the San Francisco Natural Areas Program where dog walker and tree advocate citizen groups derailed a management planning process for remnant natural areas (Garcia 2002a, b), and in rural environments, such as the ambitious Sacramento River Restoration Program where some involved farmers perceive restored areas as having negative impacts on agricultural production (Golet et al. 2006; Buckley and Haddad 2006).

Causes for social resistance to ecological restoration are multiple. However, one problem stems from a conceptual challenge to restoration ecology itself, namely, the definition of "restoration" and how practitioners and the public interpret this concept. For practitioners, there is still controversy over whether restoration should be focused on recovering ecosystems to some type of historic "pristine" reference condition or whether restoration should be viewed as a process in which future ecosystems are shaped to maximize native species persistence, ecosystem functions, and ecosystem services. For some people, the notion of moving society back towards a more "pristine" nature is a threatening prospect. Consequently, the rationale of recreating historic natural conditions may be one of the primary deterrents to public support for restoration activity.

Given the difficulties in coordinating heterogeneous restoration activities, and the challenge of generating public support for these activities, it is vital that socio-economic investments in restoration are grounded in a robust scientific framework (Falk et al. 2006). Much of the information from various projects that could help to improve restoration science is not being gathered nor communicated (Holl et al. 2003). A major problem is the lack of investment in monitoring and adaptive management. For example, Bernhardt et al. (2005) synthesized information on 37,099 national river and stream restoration projects. Only 10% of these projects had any post-implementation assessment or monitoring. Of the approximately 3700 that did receive some post-implementation evaluation, most did not evaluate consequences of restoration activities or provide for dissemination of monitoring results. Clearly, for "adaptive management" to be meaningful, there must be at least as great an investment in "learning" as in "doing" (Vasey 2003) and a much stronger effort made to engage academic scientists, students, and restoration practitioners (e.g., agency, non-profit, and consultants) in partnerships in which these adaptive management programs are designed and implemented. Such an effort should include more funding and incentives for creating effective public outreach. Perhaps, by encouraging a more "public ecology" (Robertson and Hull 2001) in which science-based alternatives are explored in a transparent manner with public stakeholders (Purcell et al. 2007, this volume), the onus to coordinate restoration activities at broader scales in a publicly supportive environment might take root.

Efforts to promote an exchange of information and opinions among land owners, government agencies, and scientists are necessarily challenging, costly, and time consuming, but essential to the success of large-scale restoration efforts. Two good examples involve the exploration of alternative futures with stakeholders in the Willamette Valley, Oregon, where GIS tools and computer models were used to explore future land use scenarios with stakeholders in the region (Baker et al. 2003) and a similar public outreach process involving large-scale management of fire-prone ponderosa pine ecosystems and the urban-wildland interface (Sisk et al. 2006). Other well publicized large-scale collaborative institutional arrangements for conserving and restoring natural resources, such as the CALFED Bay-Delta Program and the Everglades Comprehensive Restoration Plan have met with mixed success (Heikkila and Gerlak 2005). CALFED began in 1994 as a forum for federal and state agencies to develop a plan for managing the region around the San Francisco Bay and San Joaquin-Sacramento River Delta. It now includes 23 state and federal agencies responsible for adaptively managing water resources and protecting natural resources and funds a great deal of science to inform management decisions in this region (Jacobs et al. 2003; Heikkila and Gerlak 2005). It has led to dialogue among scientists, local landowners, and many government agencies, much better coordination of management activities, and an improved transparency of science that is used for decision making. But achieving these goals has been a long and arduous process, and CALFED has been criticized for spending millions of dollars without clear evidence of accomplishments.

Prospects for the Future of Ecological Restoration in California

The new definition of ecological restoration, with its focus on the recovery of ecosystem health, integrity and sustainability (SER 2004), helps to push the science and practice of ecological restoration beyond the goal of recreating historic ecosystems. In the future, ecosystems are more likely to be shaped so as to both perpetuate indigenous species and ecological functions while accommodating global change in a more flexible and adaptive framework. This conceptual shift in the focus of restoration ecology is gaining momentum (e.g., Aronson and van Andel 2005; Palmer et al. 2005; Hobbs et al. 2006; Harris et al. 2006). For example, Hobbs et al. (2006) explore the potential importance of "novel ecosystems" (i.e., "emerging ecosystems") that can be defined as "ecosystems containing new combinations of species that arise through human action, environmental change, and the impacts of deliberate and inadvertent introduction of species from other regions". Palmer et al. (2005) highlight the importance of selecting a "guiding image" for river restoration that is a realistic approximation of an achievable result: "Rather than attempt to recreate unachievable or even unknown historical conditions, we argue for a more pragmatic approach in which the restoration goal should be to move the river towards the least degraded and most ecologically dynamic state possible, given the regional context" (p. 210 in Palmer et al. 2005).

It is noteworthy that some of the most advanced thinking along these lines comes out of Europe, a region in which landscapes have been transformed by human practices for many millennia. Folke et al. (2002) and Bengtsson et al. (2003) articulate the need to tailor conservation practices to enhance resilience, defined as the "capacity to buffer change, learn and develop", and the importance of adaptation to dynamic human-influenced landscapes. Recognizing the likely influence of global change, Bengtsson et al. (2003) advocate a landscape-scale approach to preserving "ecological memory"; i.e., the species, interactions, and structures that make ecosystem reorganization possible in the face of changed conditions. Similar calls come from the contemporary American environmental movement, such as David Brower, who pointed out that "Restoration is not an effort to stop the clock, but rather a chance to keep the clock running—in fact, our best chance" (p. 99 in Brower and Chapple 1995). Brower envisioned a combination of Conservation, Preservation, and Restoration (CPR)—a metaphor for earth resuscitation—as the key strategy for recovering the earth's ecological vitality.

Given the challenges in which ecological restoration and conservation management are being practiced today in California and elsewhere, we believe that it is critical that we embrace the creative potential inherent in this more adaptive focus on shaping future ecosystems. However, moving from a general call for a broader view of restoration endpoints to making specific recommendations for how to design restoration plans in light of climate change is challenging, particularly given the uncertainty in the models that make specific predictions about how climate change will be manifested (Weltzin et al. 2003; Callaway et al. 2007). Many have suggested increasing habitat connectivity in fragmented landscapes to allow for species migration in response to a changing climate (e.g., Donald and Evans 2006; Wilmers and Getz 2005) demonstrate the importance of restoring intact food chains to buffer changing climatic conditions. Other authors have noted the need to consider whether there is sufficient genetic variation in the propagules introduced as part of restoration to allow them to adapt to and survive in future climate conditions (Rice and Emery 2003; Sáenz-Romero et al. 2006). Increasingly, there is recognition that wetland restoration projects need to be designed recognizing predicted sea level rises, although the specifics of the rate of rise are difficult to predict (Georgiou et al. 2005; Callaway et al. 2007). How to design restoration for future conditions will certainly be a growing area of research, but will necessarily remain challenging given the uncertainty regarding the many climatic feedbacks and other global changes at play (Rein et al. 2007; Suttle and Thomsen 2007; Callaway et al. 2007; all in this volume).

This broader view of restoration is likely to be more inclusive of different stakeholder's needs and, therefore, should find broader public support than a simple focus on restoring a few endangered species. But, broadening the definition of restoration potentially increases the conflicts about restoration goals and endpoints. As we have noted earlier, the primary challenges to managing in a landscape context are as much social as biological in that they involve policy coordination, overcoming social resistance, and supporting a more actively engaged scientific community in the practice of restoration ecology (Holl et al. 2003). Resolving conflicting needs will require embracing the recent movement towards stakeholder participation throughout the restoration planning, implementation, monitoring, and adaptive management process (Holl and Cairns 2002; Palmer et al. 2005). As discussed previously, this is a long and challenging process, but engaging in this dialogue from the outset is much more likely to result in success in the long run (Palmer et al. 2005).

Ultimately, the key to our ecological and evolutionary future is promoting resilience and adaptation to what are likely to become increasingly dynamic landscape processes (Folke et al. 2002; Bengtsson et al. 2003; Carpenter and

Folke 2006). Under this scenario, it is probable that ecological restoration will play an increasingly important role in shaping the future of California's ecosystems and in creating a bridge for its rich biological diversity to survive these changes as California's ecosystems experience biological reorganization. It behooves the ecological restoration community to adjust to this new reality by adopting realistic standards for restoration (Palmer et al. 2005). Also, it is essential to frame future restoration projects in a landscape context and to account for the emergence of novel ecosystems. Finally, there must be greater investment in not only doing but *learning* as well; i.e., the practice of developing robust scientific approaches to conducting active adaptive management. This will require the support of the public, government, and the scientific community—a tall order but a necessary one if the practice of ecological restoration is to be a cornerstone in sustaining California's biodiversity and its future ecological health.

Summary

Ecological restoration will be a key to conserving California's rich biodiversity, however, the future impacts and uncertainties inherent in global change require that we adjust our approach to the science and practice of restoration ecology. In particular, we need to embrace a broader definition of restoration ecology that focuses more on shaping future ecosystems rather on trying to re-invent historic conditions; i.e., place less emphasis on reference conditions. We also need to engage in landscape and regionally scaled conservation and restoration programs in which various public actors and scientists are fully engaged. And finally, we need to invest in meaningful, long-term adaptive management of restoration projects, so that we learn as we go and are able to make timely corrections and disseminate information to other practitioners.

Although the challenges are great, successful restoration projects have taught us that ecosystems are inherently resilient if we can be sufficiently flexible as a society to give them the opportunity to flourish. The key is to couple realistic restoration expectations while creating that opportunity on a broad enough scale to sustain these species and ecosystems over time.

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